from which Mr. G. Packham has identified the following (zone ranges are given in brackets): *Glyptograptus* sp., *G. tamariscus* (18–21), *G. sinuatus* (19), *Mesograptus* sp., *Petalograptus* sp. (19–22), *Orthograptus insectiformis* (19–20), *Rastrites* aff. *approximatus* (19–21) and *Climacograptus hughesi* (16–21). The forms belong to the zone of *Monograptus gregarius*, zone 19 of the British succession (Lower Llandovery, equivalent to g_1 of Four Mile Creek).

The upper limestone contains, besides corals, *Conchidium* sp., which is found in abundance in Cobbler's Creek, on the north-western side of the basin. Overlying strata are shales and siltstones with some fine-grained sandstones.

At the southern end of the basin the limestones join and diverge again to the south, where possible Ordovician limestone appears. Between Gleeson's Creek and the basalt to the west, at g_{12}, fossiliferous Silurian limestone adjoins shales with *Climacograptus* sp. and *Monograptus* cf. *gregarius*, suggesting an extension of the Lower Llandovery strata.

Upper Silurian or Devonian.

Wallace Shale.—Red and green shales of this formation overlie the Panuara Formation along Panuara Rivulet north-west of "Ashleigh". Beds of coarse micaceous arkose with irregular lenses of black shale are prominent in this area, and the base of the formation is marked on the southern side by a grey tuff with angular fragments of quartz and felspar.

Bulls' Camp Rhyolite.—The uppermost beds of the Wallace Shale grade into tuffs with pebbles and boulders of andesite which dip north under the rhyolite north of "Ulah". The rhyolite disappears to the west under Upper Devonian sandstones.

Upper Devonian.

Black Rock Sandstone.—The lithology of this formation has been noted in previous papers (Stevens, 1950; Stevens and Packham, 1953). Ripple marks and current bedding are shown in the excellent exposures on Panuara Rivulet, but no fossils have been found in this area.

Tertiary.

Trachyte.—A flow of trachyte extends south towards Angullong from the foothills of Mt. Canobolas. It is confined to the higher country between Panuara Rivulet and Cadiangullong Creek, and the base of the flow slopes southwards to an elevation of 2100 feet at the southern end. East of "Ashleigh", hills of Malongulli Formation rise to about 100 feet above the present upper surface of the flow. The maximum thickness is about 100 feet.

The trachytes are dark blue-grey and resinous when fresh, and pale grey and platy when weathered. Phenocrysts are of sanidine and the ferromagnesian mineral is probably aegirine-augite.

Basalt.—Tertiary basalt caps the ridge west of Cadia at an altitude of 2800 feet, and several outliers are present at a lower level at Angullong (2000 feet). Some basalt and trachyte also occur in the valley of Cadiangullong Creek south of Cadia, several hundred feet below the basalt and trachyte on the ridge.

Tertiary gravels beneath the basalt at Angullong have been worked for gold (Booker, 1950). A flat-topped hill west of Gleeson's Creek represents an area formerly covered by basalt.

3. Intrusive Rocks.

Monzonite and Related Intrusives.

Monzonite, associated with syenite-aplite, has been noted at Cadia (Raggatt, 1939). In mapping the district to the south, smaller intrusions of monzonite porphyry and syenite and a larger intrusion of syenitic rock have been found. The monzonite porphyries are related to the main mass of monzonite, and are similar to types collected by Raggatt from Cadia.

The western part of the larger syenitic intrusion is made up of a pink syenite consisting mainly of orthoclase and sodic plagioclase with chlorite from original amphibole or possibly biotite. East of the Angullong Road, the intrusive is a grey-green monzonite porphyry or porphyrite with phenocrysts of albitized and epidotized plagioclase and some augite in a deuterically altered felspathic groundmass.

A small intrusion of augite-syenite with a notable amount of zeolite outcrops among Silurian sediments north-east of Angullong, and an epidotized diorite has invaded the Malongulli Formation on the Belubula River south of Cadiangullong Creek.

Other Intrusions.

An intrusion of felspar-porphyry forms a gorge in the lower part of Cadiangullong Creek. The rock is conspicuous in the gravels of the Belubula River because of the large pink felspar phenocrysts. Quartz and hornblende are present in the groundmass.

Several small dykes of lamprophyre and uralitic dolerite have invaded the Malongulli Formation north of the Orange-Angullong Road (see Text-fig. 1). Some of these intrusions, associated with porphyrite, are shown in the south-eastern corner of the Four Mile Creek map.

The age of these intrusions cannot be placed more precisely than post-Ordovician, pre-Tertiary, except for the syenite which has invaded the Silurian sediments north-east of Angullong. Raggatt (1939) suggested a Kanimblan age for the Cadia monzonite.

4. Structure.

Where Ordovician sediments are well-exposed (as in Swallow and Cadiangullong Creeks), the structure is seen to be complex, with numerous minor folds and faults. Three major folds have been recognized between Panuara Rivulet and Cadiangullong Creek, with axes trending west-north-west. Many smaller folds are probably present, but they cannot be proved because of lack of outcrops or bedding.

In the western part of the area, angles of dip are gentle in both Ordovician and Silurian rocks, and there appears to be a conformity, but in other places the unconformity is evident.

At Four Mile Creek, the Panuara Formation, the Wallace Shale and the Bulls' Camp Rhyolite dip to the west, but further south, a number of close folds appears in the lower formations. Still further south the angles of dip become more gentle and the structure is seen to be a syncline with minor undulations, plunging north-west. The three formations disappear west under the Upper Devonian sandstones, and the disposition of these rocks indicates that the Panuara Formation, the Wallace Shale and the Bulls' Camp Rhyolite are all conformable. The unconformity between them and the Black Rock Sandstone is quite obvious.

The two most important faults are those between the Panuara Formation and the Angullong Tuff at "Ashleigh", and the fault separating the Angullong Tuff and the Malongulli Formation on Swallow Creek, with its possible extension on the Belubula River. At "Ashleigh" the basal limestones of the Panuara Formation are missing and the Silurian rocks are heavily sheared at the contact with the Angullong Tuff. To the south, beds of the Panuara Formation appear to dip east under the tuff. The fault on Swallow Creek has overfolded siltstones, and on the Belubula River there is a wide zone of sheared rocks south of this point.

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GUSTAVUS ATHOL WATERHOUSE, 1877–1950.

(*Memorial Series, No. 14.*)

(With Portrait,* Plate xviii.)

Gustavus Athol Waterhouse was born at Waverley, Sydney, on 21st May, 1877. The old home in which he spent his early years is now portion of the War Memorial Hospital, Waverley. His first school was the Waverley Public School where he received from the Headmaster (Mr. Harrison) a thorough grounding in mathematics. He went on to the Sydney Grammar School in 1890 and had there a distinguished scholastic record, gaining the Medal for Trigonometry at the Senior examination in 1895.

He was brought up in an atmosphere of natural history. His father, Gustavus John Waterhouse, was an enthusiastic collector of Pacific Island weapons and implements, and his mother was a noted collector of shells from the beaches in the neighbourhood of Sydney. He, with his two younger brothers, took part in this shell collecting and paid many visits to such localities as Watsons Bay, Bottle and Glass Rocks, Little Manly, Balmoral and Botany Bay. During one of these excursions in search of cowries, he levered up a large slab of rock and was in such a position that, had he relinquished his hold on the rock, he would have been caught under it and probably severely injured. The effort of holding the rock until assistance was forthcoming resulted in such a strain on his heart that he later had to give up his participation in active sport on account of it. He had taken a keen interest in cricket and in tennis, and for a time his love of sport overshadowed his passion for natural history field work and collecting. During his years at Sydney Grammar School he spent many lunch hours in the galleries of the Australian Museum, which adjoins the school.

In the list of exhibits at the Third Annual Exhibition of the Field Naturalists' Society of New South Wales, held in 1893, there is an entry "Master Athol Waterhouse—collection of Australian Shells". The Council of the Society about that time included a group of naturalists that must have been a wonderful inspiration to a boy such as Waterhouse with a keen interest in collecting the local fauna. This group included A. H. S. Lucas, Charles Hedley, W. W. Froggatt, J. P. Hill, W. J. Rainbow, Thomas Steel and T. Whitelegge, each a noted name in the annals of natural history in Australia.

Waterhouse went on to the University of Sydney in 1896, and graduated Bachelor of Science in 1899 with First Class Honours in Geology and Palaeontology, and Bachelor of Engineering in 1900. Under the guidance of Professor Edgeworth David he made a special study of the volcanic dykes intruding the Triassic Rocks of the Sydney district and prepared a detailed map of the distribution of the dykes. In 1924 he obtained the degree of Doctor of Science, with University Medal, for a thesis based on his extensive work on hybridization in butterflies of the genus *Tisiphone*.

In 1900 he was appointed to the assay staff of the Sydney branch of the Royal Mint, and he remained on that staff until the branch was closed in 1926 when he retired. In 1928 he joined the newly-formed Division of Economic Entomology of the Council for Scientific and Industrial Research as one of its first officers—with the title of Curator and Administrative Officer. He played a very important part in all phases of the early organization of this Division. With characteristic enthusiasm and vigour he hunted for staff, with considerable success, and he arranged temporary accommodation until the permanent building was erected on the slopes of Black Mountain, Canberra. He was largely responsible for the planning of this building and for the provision of scientific equipment. He also helped in the design of several large glasshouse insectaries which

* Portrait taken 1924.

are still in use. After occupying a truly key position during this early formative period he resigned when the Division became fully established in Canberra in 1930.

After graduation he commenced active participation in the affairs of scientific societies—an interest which he expanded and maintained for nearly forty years, when indifferent health compelled him to relinquish the last of his honorary offices. The Field Naturalists' Society of N.S.W. had ceased active existence in 1893, and Waterhouse took an active part in its revival as the Field Naturalists' Club in 1900. He was Honorary Secretary of this Club from 1900 to 1905, Vice President and Honorary Librarian in 1905–06, and President 1906–07. While he was President he offered a prize, for the best collection of insects, to Junior Members of the Club; collections submitted by Sydney Members to be from the County of Cumberland, and by country Members from their own districts. The Club later became the Naturalists' Society of New South Wales and Waterhouse was elected President for 1914–15.

He joined the Linnean Society of New South Wales in 1897, and was a member of the Council from 1912 to 1943. He was President for two years, 1921–23, Acting Secretary in 1927, and Honorary Treasurer 1926–28 and 1930–43. During his term as President he made one of the first public suggestions of a central home for the scientific societies in Sydney. Replying to the toast of the Visitors at the annual dinner of the Royal Society of New South Wales he reminded the assemblage that Burlington House in London was a building which housed a number of kindred societies, and drew attention to the coincidence that the function at which he was speaking was taking place in the Burlington Cafe. Might that, he said, be an omen that the time was ripe for some move to be made in Sydney to bring together the scientific societies in a suitable building. It may be that this speech crystallized ideas which had been mentioned informally from time to time. Whether or not that was so, discussions were held during the next few years, the Government was approached and asked to make available a suitable piece of land, and ultimately an Act was passed by Parliament granting to the Royal Society of New South Wales, the Linnean Society of New South Wales, and the Institution of Engineers, Australia, jointly the piece of land in Gloucester Street on which Science House was built. Waterhouse took an active part in these preliminary negotiations and he was a member of the Management Committee of Science House in its earlier years.

He took also an active part in the administration of the Royal Zoological Society of New South Wales, of which he was a Member of Council for many years and President in 1924–25. Of the Australian and New Zealand Association for the Advancement of Science he was Hon. General Treasurer from 1934 to 1946, and was President of Section D (Zoology) at the Auckland meeting in 1937. He was a member of the Australian National Research Council from 1926 till his death, and a member of the Executive Committee for some years. He joined the Royal Society of New South Wales in 1921 and for two years (1923–25) acted as Honorary Secretary in order to free Mr. R. H. Cambage for work connected with the Second Pacific Science Congress which was held in Australia in 1923.

He was Honorary Entomologist to the Australian Museum from 1919, an Elective Trustee from 1926 to 1947, and President of the Board of Trustees in 1930.

This is an outstanding record of voluntary service in the cause of science in Australia and there are few who can claim to have made such a continuous and successful contribution.

The Royal Entomological Society of London conferred on him the unusual distinction of Honorary Life Fellowship—an honour of which he was justifiably very proud.

His lifelong interest in zoology was mostly concentrated in collection and study of the Butterflies of Australia. His collection which ultimately became the finest existing collection of Australian species was commenced in 1893 while he was still at school. It is now preserved in the Australian Museum, to which he presented it about 1935. Of nearly 350 known Australian species, only four species are not represented in this collection. The Australian Museum collection contains all except 16 of the 888 specimens used as illustrations in "The Butterflies of Australia". The collection also contains all

of Waterhouse's own types except one which is in the Macleay Museum, University of Sydney, and a few described with G. Lyell which are in the National Museum, Melbourne.

In addition to specimens collected by himself during trips to every State, his collection contains valuable specimens from many well-known collectors such as H. Elgner (Cape York), F. P. Dodd (Kuranda), R. E. Turner (Mackay, Kuranda and Cape York), L. Franzen and R. Illidge (Brisbane), G. M. Goldfinch (Sydney), and F. L. Whitlock (Western Australia).

There are five drawers of the magnificent species of *Ogyris*, most of the species being represented by long series of bred material. This genus, with the exception of a few New Guinea species, is confined to Australia. The collection also includes some thousands of specimens of Indo-Malayan species as well as specimens from Ceylon, Japan and the Pacific Islands.

Other unique features include the 300 specimens of the first, second and third generations of the crosses of *Tisiphone abeona* referred to below, a considerable number of colour aberrations, mosaic gynandromorphs, and other abnormal specimens, as well as a large amount of larval and pupal material. Waterhouse prepared extensive notes on this material and on the details of life histories, but unfortunately little of this information has been published.

Waterhouse began collecting butterflies at the age of 16, and 10 years later (1903) had amassed sufficient data to publish a catalogue of Australian butterflies containing 329 species, of which 283 species were represented in his own collection. This published list contained 79 species more than in Miskin's 1891 catalogue. The comprehensive nature of this work is illustrated by the fact that, by 1914, the number of species had been increased by only four, and by 1942 by only a further eight species. Only one new species has been described since 1942. Thus, in the last 50 years, only about a dozen new species have been added to a fauna of nearly 350 species. During the same time well over 100 new subspecies were described by Waterhouse from a vast amount of material collected from many parts of Australia.

Waterhouse's extraordinary thoroughness as a taxonomist may be illustrated by the fact that he examined in detail and made careful notes on about 480 types of Australian butterflies, including species and subspecies. Of the 134 remaining it is definitely known that 51 are lost and it is highly probable that a further 40 no longer exist. His determinations were made, therefore, with a vast background of knowledge, which extended beyond the Australian species to include the Pacific, Malayan and Indo-Malayan butterfly faunas. He described about 16 species of Australian butterflies and well over 100 geographical subspecies. It is probable that very few new species of butterflies remain to be found in Australia, except perhaps in the relatively uncollected far north-west. Few groups, therefore, of the Australian insect fauna are as thoroughly described as butterflies.

Waterhouse's Presidential Addresses to the Linnean Society of New South Wales in 1922–23 detailed the results of breeding experiments in respect of hybridization of certain species of butterfly. These experiments were mainly with the satyrid genus *Tisiphone* and were carried out in the grounds of his own home where he built special cages to which he transplanted specimens of the food plant of the species. His notebook and card catalogue with details of these experiments are preserved in the library at the Australian Museum. This work is an excellent example of his very broad taxonomic interests. Between 1914 and 1928 he made extensive collections of the geographical subspecies of *T. abeona* and in 1921 was able to cross the subspecies *abeona* and *morrisi*. These crosses were carried to the third generation and the offspring approached closely the extremely variable suspecies *joanna* which occurs around Port Macquarie. Later by studying the progeny of single female *joanna* he demonstrated that this variability was due to the hybrid nature of this subspecies. In addition, the results of crosses between the subspecies *abeona* and *rawnsleyi* suggested that the latter (the more northern subspecies) was derived from *morrisi*.

This study (summarized in *Aust. Zool.*, 5:217, 1928) was a pioneer work in experimental taxonomy and even today there are few examples of the "laboratory" synthesis of a naturally-occurring hybrid subspecies. It is unfortunate that these important studies have not become better known.

Almost all of Waterhouse's published scientific work deals with butterflies and includes, besides papers in the publications of scientific societies, the Catalogue of Rhopalocera of Australia (1903), The Butterflies of Australia (1914, with G. Lyell), and What Butterfly is That? (1932). His own first-printed interleaved copy of "What Butterfly is That?" in which his subsequent notes and annotations are written, together with his scientific books are preserved in the library of the Australian Museum.

His Presidential address to Section D, delivered at the 1937 meeting of the Australian and New Zealand Association for the Advancement of Science, gave a comprehensive account of the biology and taxonomy of Australasian butterflies. This address contained many of the results of his observations on type specimens and early literature made during a visit to England in 1936.

During this visit to England he worked almost daily at the British Museum (Natural History) examining types and other material, including the Banks Collection. The Museum had asked him to come to London to classify its collection, which began with specimens collected by Sir Joseph Banks and Captain Matthew Flinders. He also spent some time examining Lord Rothschild's Collection at Tring and Meyrick's Collection of Lepidoptera at Marlborough.

For any ordinary man it might be expected that an absorbing interest in Lepidoptera and intense activity in scientific societies would occupy all the leisure time available. But Waterhouse was remarkably active, both physically and mentally, and always had some interests in addition to those mentioned. About 1900 he was interested in the distribution of basic volcanic dykes in the Triassic Hawkesbury Sandstone Series in the Sydney district; for many years he collected Mollusca, of which his mother presented a fine collection to the Australian Museum; and he was a keen philatelist. He was a director of E. Vickery & Sons Pty. Ltd. for about fifteen years, and also took an active part in the management of The Coal Cliff Collieries Ltd., of which he was a director for many years and Chairman of Directors 1938–1943.

From 1943 onwards his health compelled him to relinquish gradually his scientific activities and this was a source of great disappointment to him. He did rally for a period in 1946–47 when it became known that butterfly collections in a number of Australian museums had been subject to a series of ingenious thefts. The collections affected included that which he had presented to the Australian Museum. Most of the specimens were recovered and from his personal knowledge of the specimens in his collection and the localities from which they came he was able to remedy much of the confusion resulting from changed locality labels and thus render a final important contribution to his own special subject. This task would have proved impossible were it not for the excellence of the Register of the collection, in which details of every specimen in the collection were meticulously recorded.

In 1914 he was rejected for military service, but for a period during World War I he put aside his entomological work and devoted his spare time to war service in his own district. He was instrumental in organizing the Roseville Rifle Club and as Captain of the Club drilled and marched over hill and road, exchanging his butterfly net and other collecting paraphernalia for a rifle.

Waterhouse was in the widest and truest sense a very learned man. Apart from science the breadth of his learning was amazing and his brain a storehouse of knowledge which was encyclopaedic. In his younger days he was deeply interested, among other things, in ancient history and always kept within easy reach his favourite volumes—the works of Bryce, Gibbon and Macaulay. Throughout his life he answered a continuous stream of questions coming from old and young alike. His questioners never failed to receive full and satisfying answers, except on those rare occasions when, if he did not know, he said so with conviction. It was axiomatic within his family and outside it